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EFFECT OF SiC PARTICLES ON COMPRESSIVE STRENGTH AND FRACTURE FEATURES OF GLASS/PHENOLIC COMPOSITES

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Introduction

Composites constitute an important part of modern materials in high technology applications. Polymer composites have a high strength to weight ratio and are easy to fabricate. Generally epoxy and polyester resins as matrix materials have attracted the attention of investigators for possible filling, either by organic or inorganic filler materials, or reinforcing by fibrous materials. The literature survey in the recent past on phenolic resins, in general, and on filled or laminated phenolics, in particular, yielded only a few references (1,2).

Phenolic resins play an important role in the aviation industry as they are strong fire retardants and hence can be used as ablatives. Unlike phenolics, epoxies and polyesters, when burnt, give rise to fumes which lead to asphyxiation and choking, thus severely restricting their role in thermal and hyper atmospheric fields. However, composites with phenolics as a matrix suffer from inferior mechanical properties due to a high void content (3) resulting possibly from condensation products (4) and somewhat inferior adhesion to reinforcement materials.

It has been reported that glass bead filled polyesters tend to draw a lot of water from the atmosphere at the interface due to the high specific surface area of the particle and stress concentrations around the particles (5). Stress concentrations arise because of the difference in shrinkage between resinous material and the fillers used. Hence, it is quite possible that the more the volume fraction of fillers more is the likelihood of adsorption of moisture at the interface.

This possibility of filler material adsorbing products of condensation prompted the selection of hard particles of SiC with high modulus, very irregular shapes and surface as filler material in a matrix of phenolic resin reinforced with glass cloth. The present study is in pursuance of an earlier study in which the effect of SiC particulates on interlaminar shear strength (ILSS), impact and flexure properties of glass phenolic composites was studied (6). It was reported in that work that in

all the above tests, with increasing SiC content, the composites showed initial drop after which a rising trend was noticed. Whether such a behav would be exhibited also in compression formed the basis of the present wo Post failure fracture features were also studied through fractograph techniques in order to understand the compressive failure behaviour unfilled and filled composites.

Experimental Techniques

E-glass of 0.175 mm thickness, plain weave and having a density 2.75 g/cc formed the reinforcement material. The resin employed was th hot curing grade R-88084 phenolic resin (supplied by Bakeli Hylam,Hyderabad). No hardener was used, as the resin was self setting type Irregular shaped SiC particles with rough surface and a size range of 5 to micro meters constituted the particulate additions.

Laminates of thickness 3.2mm were prepared by a hand lay-u technique from the cloth pieces, 18 in all, measuring 225*225 mm. Afte applying the resin, these were clamped in iron plates and cured at 160 C fo 2 hours followed by cooling in the oven. The amounts of resin and glass clot had a ratio of 1:1 by weight. SiC particles were introduced into the resin i the range 1 to 4 % by volume of resin. Care was taken to avoi agglomeration of particles.

Compressive test samples prepared according to standard specification (7), were tested at two width to thickness ratios of 2 and 5. The former test samples had dimensions of 15*6*3.2 mm, while the latte measured 15*15*3.2mm. Compression tests were carried out in a servo hydraulic test machine, Instron-8032, with a cross-head velocity of 0.021 mm/s. The fractured surfaces of the failed test specimens were sputter coated with gold and examined in a JEOL-840A scanning electron microscope.

Results and Discussion

Figure 1 records the change in compression strength with SiC addition. Test data for both the width to thickness ratios used here showed a similar behaviour in that there is a fall in the value of the compressive strength up to 1 % and subsequently a rising trend is seen. The samples with higher width to thickness ratio recorded lower values, which might be due to the possibility of some degree of sample slipping taking place during the tests. Interestingly, at larger percentages of fillers added to the composites, the compressive strengths were higher than for unfilled ones. Here again, tests with a smaller ratio yielded a greater increase in strength values. This trend of an initial fall and a consequent rise in both the tests shows a similarity with earlier work concerned with other mechanical tests (6). To explain this behaviour, the possibility of moisture adsorption by SiC particles leading to a decrease in void formation was invoked (6).

Condensation products can diffuse out through the matrix or the glass/resin interface. Alternatively they could settle at the glass/resin or particle/resin interface or inside the resinous matrix itself. At the glass/resin interface the concentration of stress is much less than that at the particle/resin interface due to a greater modulus

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difference between the particle and resin system. Furthermore, the particles which are well distributed in the matrix can be reached by the products of condensation with ease, the greater the volume fraction of fillers for a fixed size of additions. Such a situation could facilitate the adsorbtion of moisture on the surface of the filler materials.

Figure 2 shows a fractograph of an unfilled composite having a large number of voids clustered in a localised region, while figure 3 depicts features in a 4 % filled composite with greatly reduced void content. It can be inferred from this that SiC particles play a definite role in decreasing the void content. This decrease in void content, when coupled with the presence of an inorganic filler, is important during compression testing. For the low content of fillers, the filler surface area being made available is less and hence the void elimination process is incomplete. Furthermore, the possibility of SiC / resin interfaces being used for adsorption and consequent weakening (see figure 4, in which a poor interface is observed in a composite containg 1% filler additions), is greater. In such situations the composite exhibits properties which are inferior to the unfilled ones, thus accounting for the initial fall in values (Fig.1).

With an increase in filler content, the filler surface area increases. This enhanced area available is utilised for increased moisture adsorption, which should show a trend towards saturation and partly for resin smearing by the matrix material. The latter aspect can be clearly seen in the composite containing 4 % filler; in which the particle is well smeared by resin, indicating good adhesion at the resin/particle interface, (Fig.5). Hence, the overall adhesion of resin/particle interface improves with increasing filler content. It is this aspect of good adhesion coupled with decreased void content that leads to higher strength levels in composites containing larger additions of filler material. In the 4 % filled sample a well developed crack narrowing down near particle is seen (Fig.6). The top portion of the micrograph contains the resin that is clearly deformed. This suggests that the particles can play a significant role in arresting the crack propagation.

Conclusions

SiC filled glass/phenolic composites in the range 1 to 4 % were prepared and their compression behavior and fractographic features were studied. Compression tests yielded an initial drop in the strength following which a rising trend was noticed. The void formation decreased with increasing filler content, and this was attributed to adsorption of moisture by fillers. The initial fall and subsequent rise in compressive strength was explained in terms of interface weakening by moisture, decreased void content due to fillers, and an improved interface at higher filler additions. Further studies on the effect of higher SiC volume content and size and modulus of fillers on the mechanical properties and fracture features need to be carried out in order to assess the overall utility of such fillers in improving the mechanical properties.

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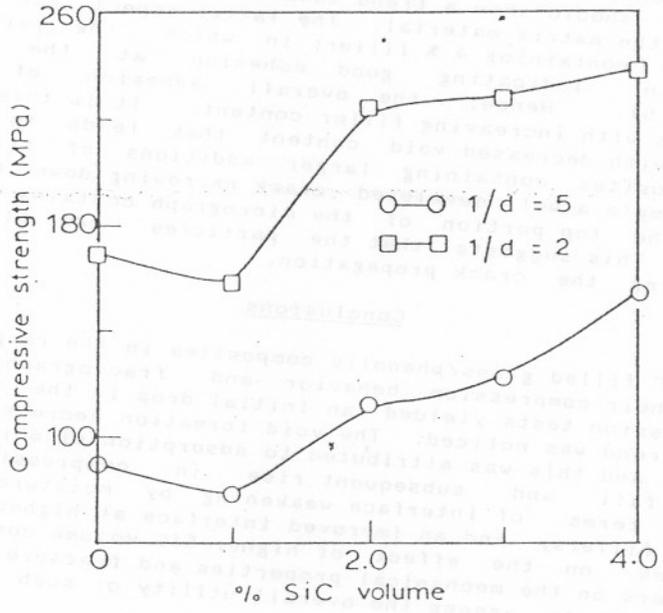

Fig.1 :Variation of compressive strength with SiC additions.

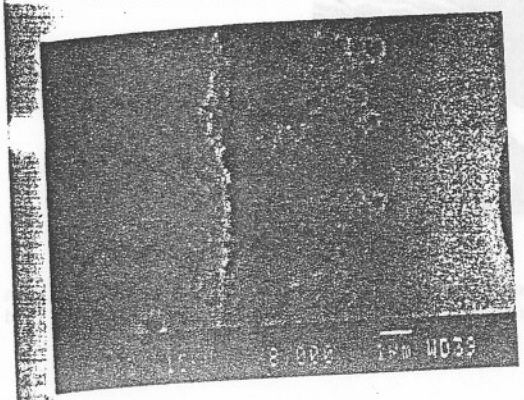

Fig.2 :SEM photograph depicting void formation in an unfilled composite.

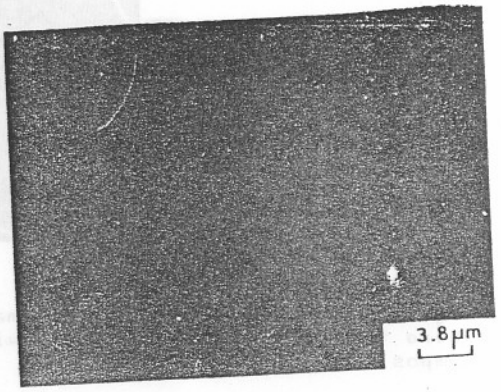

Fig.3 :Fractograph of a 4% filled composite showing considerably reduced void content.

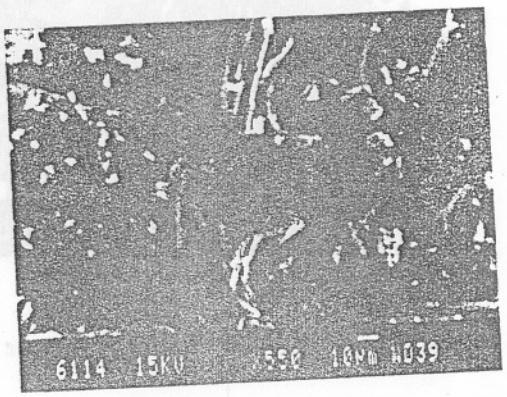

Fig.4 :Interface separation in a composite containing 1% filler addition.

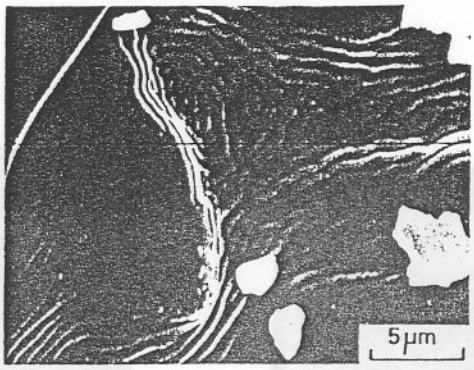

Fig.5 :Flow patterns of the matrix resin as well as in the region where the particle is smeared with resinous material in a 4% filled composite.

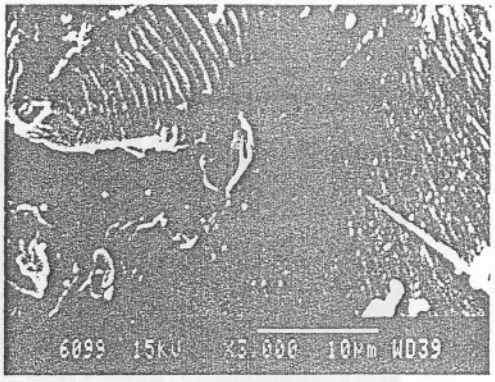

Fig.6 :A failure feature depicting the narrowing of a crack near a SiC particle.